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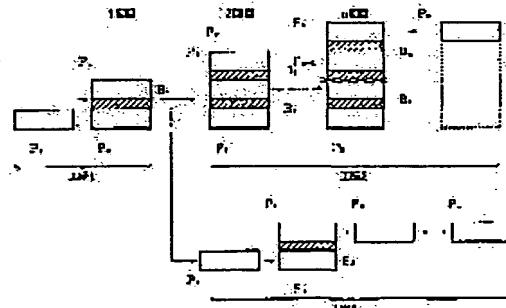
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(54) GAN SINGLE CRYSTAL AND ITS PRODUCTION

(57)Abstract:

PURPOSE: To obtain a high-quality GaN single crystal having enough thickness to be usable as a substrate singly.

CONSTITUTION: This GaN single crystal is such that the full width at half maximum in its double crystal X-ray rocking curve stands at 5–250sec and its thickness $\geq 80\mu$ m. This single crystal can be obtained by film formation, as buffer layers, of a substance good in the lattice conformity with the GaN single crystal on a substrate with at least its surface representing GaN single crystal and then by crystal growth of the aimed GaN. There are two alternatives in this production method depending on the method of removing the buffer layers: one method is as follows: the above-mentioned crystal growth cycle is repeated desired times and laminates are formed on the substrate P0 and then the respective buffer layers B1–Bn are removed at a time to obtain GaN single crystals P1–Pn; the other method is as follows: a buffer layer is removed at every cycle and the above-mentioned crystal growth cycle is repeated for a GaN single crystal singly at all times. These two alternative methods may be combined with each other.



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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] this invention relates to the quality GaN single crystal which can be suitably used as GaN single crystal substrates, such as blue light emitting diode, and its manufacture method.

[0002]

[Description of the Prior Art] The appearance of the semiconductor device which can emit light for the short wavelength which reaches a blue shell ultraviolet-rays wavelength field is strongly searched for by the demand of multiple-colorizing in a luminescence display etc., and the demand of the improvement in data density in communication, record, etc. Its attention is paid to the GaN system single crystal which is the latus nitride of a band gap most in a III-V system compound semiconductor as a semiconductor material this blue – for ultraviolet luminescence devices. Since GaN has a transited [directly] type band structure, since the band gap in a room temperature is as large as about 3.4eV, it presents blue – ultraviolet luminescence possible [efficient luminescence], and it is a suitable material for the demand of the above-mentioned semiconductor device. However, since [that crystal-growth temperature of GaN is high and] the equilibrium vapor pressure of the nitrogen near crystal-growth temperature is high, it is very difficult to manufacture a large-sized single crystal for high quality from a melt. Therefore, growth of a GaN system single crystal was performed by the hetero-epitaxial grown method based on the non-static reaction by MOVPE (Metal Organic Vapor Phase Epitaxy) or MBE (Molecular Beam Epitaxy) to an excellent in thermal resistance silicon-on-sapphire, or SiC substrate top. On the other hand, the method of having formed membranes upwards on silicon on sapphire by making ZnO into a buffer layer, and growing up a GaN single crystal was indicated (for example, Applied physics letter Vol.61 (1992) p.2688), and production of a GaN substrate was attained in recent years. By growing up a homogeneous GaN system single crystal thin film on this GaN substrate, the quality of a GaN system single crystal thin film improved compared with the direct crystal growth to the above-mentioned silicon-on-sapphire top.

[0003]

[Problem(s) to be Solved by the Invention] However, by the conventional method using Above ZnO as a buffer layer, since membrane formation of ZnO to a silicon-on-sapphire top was what is depended on the sputtering method, this ZnO layer did not become a quality single crystal, but since the quality of this crystal structure influenced the following GaN single crystal layer, there was a problem that a quality GaN single crystal was not obtained. Moreover, the crystal quality of the GaN single crystal known conventionally Even if the quality, the full width at half maximum (full width at half-maximum of the double-crystal X-ray rocking curve) of 2 crystallization X-ray rocking curve About 100 secs, Mobility in a room temperature Although it was 600cm² / VS grade Since the method of growing up a crystal was MOVPE, it was difficult to separate a GaN single crystal from the substrate of a basis by not obtaining only about 5 micrometers of thickness, since it is very thin, for example, to use independently as a substrate of a semiconductor light emitting device. For this reason, when a GaN single crystal was used, it was obliged to use still in the state where it was formed on the substrate of a basis.

Hereafter, on these specifications, "2 Full width at half maximum of a crystallization X-ray rocking curve" is only called "full width at half maximum." Moreover, although the thing of thickness with the GaN single crystal sufficient as a substrate grown up by HVPE (Hydride Vapor Phase Epitaxy) on the ZnO buffer layer was obtained as mentioned above, the full width at half maximum of the quality was the thing of low quality of 300 or more secs. That is, there was no GaN single crystal which has good quality and sufficient thickness simultaneously.

[0004] The purpose of this invention is a quality single crystal, and is offering the GaN single crystal which has such sufficient thickness that using as a substrate independently is possible. Other purposes of this invention are quality single crystals, and are offering the manufacture method of a GaN single crystal which can manufacture the GaN single crystal which has such sufficient thickness that using as a substrate independently is possible.

[0005]

[Means for Solving the Problem] Even if a GaN single crystal is the crystal structure of low quality by the conventional manufacture method, this invention person etc. Even if it is a crystal of those other than GaN(s), such as silicon on sapphire, these or as first crystal substrate By grid adjustment with a GaN single crystal carrying out thin film growth of the good matter, considering as a buffer layer besides, and carrying out the crystal growth of the GaN on this As that a more nearly quality GaN single crystal is obtained and the GaN single crystal concerned are used as a new substrate and a buffer layer and a GaN single crystal are again grown up on this It responded for repeating growing the buffer-layer matter and GaN epitaxially by turns, and the GaN single crystal was improved more in quality, found out that it could form in sufficient thickness, and completed this invention.

[0006] The GaN single crystal and its manufacture method of this invention have the following feature.

(1) The GaN single crystal whose thickness the full width at half maximum of 2 crystallization X-ray rocking curve is 5-250sec, and is 80 micrometers or more.

(2) The manufacture method of a GaN single crystal of having the process which was made carrying out thin film growth of the good matter of grid adjustment with a GaN single crystal, turned to the buffer layer up on the substrate whose front face is a GaN single crystal at least, is made carrying out the crystal growth of the GaN, and obtains a GaN single crystal.

(3) Make into 1 time of a crystal-growth cycle the process which was made to carry out thin film growth of the good matter of grid adjustment with a GaN single crystal, turned to the buffer layer up on the substrate whose front face is a GaN single crystal at least, is made to carry out the crystal growth of the GaN, and obtains a GaN single crystal. The manufacture method of the GaN single crystal characterized by removing each buffer layer after making 1 cycle repeat ***** from the above-mentioned crystal-growth cycle at least on the obtained GaN single crystal, and obtaining a GaN single crystal.

(4) Make into 1 time of a crystal-growth cycle the process which was made to carry out thin film growth of the good matter of grid adjustment with a GaN single crystal, turned to the buffer layer up on the substrate whose front face is a GaN single crystal at least, is made to carry out the crystal growth of the GaN, and obtains a GaN single crystal. The manufacture method of the GaN single crystal characterized by removing a buffer layer for the above-mentioned crystal-growth cycle for every [1 cycle repeat and] cycle at least, and obtaining a GaN single crystal by using the obtained GaN single crystal as a new substrate.

[0007]

[Function] The GaN single crystal of this invention is formed on a substrate by repeating membrane formation of a buffer layer, and the crystal growth of GaN in cycle by turns again. Many dislocation, a stacking fault, etc. which exist in a substrate disappear by the inside of the crystal-growth layer of GaN, and a buffer layer, or the interface of a substrate and a buffer layer or the interface of a buffer layer and a GaN crystal-growth layer. Therefore, whenever it performs this crystal-growth cycle once, it is thought that it will be asymptotically converged on single crystal structure which is specified on growth conditions if the quality of the single crystal structure of GaN improves and this is repeated infinite. If the GaN single crystal obtained by the manufacture method of this invention has good quality and it is required for it, it can be formed

even in the thickness of 80 micrometers or more, and will become desirable as a substrate of a semiconductor light emitting device especially.

[0008]

[Example] Hereafter, an example is given and this invention is explained more to a detail. The GaN single crystal of this invention has sufficient thickness of 80 micrometers or more, so that the full width at half maximum can show the value of 5~250sec and can use [quality] it as a substrate independently, as described above. In this invention, quality of a GaN single crystal was made into the quality of a GaN single crystal with the value of full width at half maximum shown by this method, using an X-ray diffraction method as a method for expressing numerically. An X-ray diffraction method is a method of using diffraction of the X-ray irradiated by the crystal. Also in it, by this invention, in order to raise the accuracy of measurement, it measured by the method of using two crystals. The X-ray diffraction method using two crystals is a method of evaluating the lattice constant of a sample precisely and evaluating the integrity of a crystal from the half-value width. In the quality evaluation of the GaN single crystal in this invention, the X-ray which carried out incidence from X line source was highly monochrome-ized by the 1st crystal, the GaN single crystal of the sample which is the 2nd crystal was irradiated, and full width at half maximum (full width at half-maximum) centering on the peak of the X-ray diffracted from this sample was measured. In X line source, it is Cukalpah1. It used and the X-ray was generated in 30kV and 10mA. germanium (400) was used for the 1st crystal for monochrome-izing. Measurement shall be performed about the diffraction peak of GaN (0002), and the step interval of measurement shall be performed at 0.002 degrees.

[0009] The manufacture method which it shall mention later about the experimental value of the quality of the GaN single crystal by this invention, and can next obtain the GaN single crystal of such quality is explained. Drawing 1 is drawing showing typically an example of the formation process of the GaN single crystal by the manufacture method of this invention. the first substrate P0 whose front face is a GaN single crystal at least as this draftsman shows the manufacture method of the GaN single crystal of this invention most briefly to 1 grid adjustment with a GaN single crystal deposits the good matter upwards -- making -- buffer layer B1 ** -- it turned up, the crystal growth of the GaN is carried out, and a GaN single crystal is obtained

[0010] The manufacture method of the GaN single crystal of this invention is the substrate P1 of the layered product formed by this draftsman at the process 1 again as shown in 2. Grid adjustment with a GaN single crystal turns the thin film growth of the good matter up, and it is buffer-layer B-2. Substrate P2 which formed upwards, is made to carry out the crystal growth of the GaN, and consists of a GaN single crystal It is made to form. counting a process 1 with the 1st time, and repeating such a process n times in cycle -- the best layer -- GaN single crystal Pn each buffer layer accumulated till then after growing up -- at once -- removing -- GaN single crystal P1 ~ Pn dissociating -- many -- it is the method of using as the GaN single crystal of several sheets although the crystal quality of GaN obtained improves by the above-mentioned method whenever it increases the number of cycles, after improvement in crystal quality reaches equilibrium -- rather -- many -- it will become useful as several substrates production technology

[0011] Further, as shown in 3, this draftsman the manufacture method of the GaN single crystal of this invention Buffer layer B1 of a process 1 It removes and is the GaN single crystal P0 and P1. It dissociates. Independent substrate P1 of a GaN single crystal It obtains and is the substrate P1 concerned. Grid adjustment with a GaN single crystal turns the thin film growth of the good matter up, and it is buffer-layer B-2. It formed upwards, the crystal growth of the GaN is carried out, and it is buffer-layer B-2. It removes and is the GaN single crystal P1 and P2. It dissociates. The GaN single crystal Pn is obtained by counting a process 1 with the 1st time, and repeating such a process n times in cycle. That is, this method is the method of always using the GaN single crystal which removes the buffer layer which became the foundation of the crystal growth whenever the GaN single crystal newly obtained carried out the crystal growth for every cycle, and is newly obtained as a GaN independent single crystal. After improvement in crystal quality reaches equilibrium like the above-mentioned process 2 also in this method, it uses as a product material, and also two GaN single crystals separated by removing a buffer layer may be

respectively used again as a substrate of the following GaN crystal-growth cycle.

[0012] Moreover, it considers as the method of compounding suitably two methods shown in processes 2 and 3, and how to remove a buffer layer to every number of times k with an arbitrary crystal-growth cycle can be considered. You may choose freely the arbitrary number of times k in this case.

[0013] As mentioned above, by repeating a crystal-growth cycle, whenever the crystal structure of GaN performs this crystal-growth cycle once, quality improves, and the manufacture method of the GaN single crystal of this invention is the GaN single crystal Pn very quality to the n-th desired number of times. It is obtained.

[0014] Thin film growth of a buffer layer has the desirable forming-membranes method which can grow epitaxially especially to upgrading of the GaN single crystal obtained, although the well-known forming-membranes method and a crystal-growth method are used. Moreover, the forming-membranes method which can grow epitaxially is desirable to upgrading like [the method of carrying out the crystal growth of the GaN to up to a buffer layer] thin film growth of a buffer layer.

[0015] Epitaxial growth is the method of growing up the same matter as this, or the matter of the same crystal structure on a crystal substrate as a single crystal with which the sense of the crystallographic axis was equal to the sense of the crystallographic axis of a substrate. In this invention, the forming-membranes method for growing the matter used as GaN or a buffer layer epitaxially is the most desirable, and VPE (Vapor Phase Epitaxy), HVPE, MOVPE, MBE, GS-MBE (Gas Source MBE), CBE (Chemical beam Epitaxy), etc. are mentioned especially.

[0016] Especially the number of times n that repeats the above-mentioned crystal-growth cycle is not limited, and although it may determine the number of times of a cycle according to the number of sheets of the GaN crystal substrate to need, corresponding to the quality of the GaN crystal for which it asks, in order to use as a GaN crystal substrate for the usual semiconductor devices, it serves as crystal quality sufficient by two – about 5 times.

[0017] Although the method of removing the above and the buffer layer used as the foundation of the crystal growth of GaN may be what method as long as it is the method that the obtained GaN single crystal may be separated, its chemical removal method by the acid etc. is effective.

[0018] What has grid adjustment good [the matter used for the above-mentioned buffer layer] with a GaN single crystal is used. A GaN single crystal and the good matter of the affinity made from a grid say that in which the lattice constant of the a-axis in a crystal lattice also has the Ur Die Zeit type crystal structure which is less than **5% preferably less than **10% to it of a GaN single crystal. ZnO is mentioned as a desirable example of the matter with which are satisfied of this. The lattice constant (the length of a unit lattice) of the a-axis of ZnO is 3.2496A, and since it is equipped with +1.9% and the lattice constant approximated very much to the lattice constant of 3.189A of the a-axis of GaN and the good crystal growth of GaN can perform it, it is desirable. Moreover, the etching removal nature of ZnO by the acid is good, and suitable for it as matter used for a buffer layer also at this point. The thickness of a buffer layer has 0.01 micrometers – desirable about 100 micrometers.

[0019] The first substrate P0 That whose front face is a GaN single crystal at least is used. That is, they are the independent substrate of the GaN single crystal with which the whole consists only of GaN substantially, or the substrate [as / only whose front face which has a GaN single crystal layer on the front face by the side of the buffer stratification is a GaN single crystal]. In the case of the latter, what has the thermal resistance good as base-material matter which supports a GaN single crystal layer to the growth temperature (1000–1100 degrees C) of a GaN single crystal is desirable, for example, a sapphire crystal substrate, Si substrate, crystal, a ZnO substrate, a SiC substrate, etc. are illustrated. Formation of the GaN single crystal layer to these base-materials matter top can be performed by the hetero-epitaxial grown method based on the non-static reaction by the MOVPE method, the MBE method, etc.

[0020] [A manufacture experiment of a GaN single crystal and quality check experiment] Next, a GaN single crystal is actually manufactured by the manufacture method of the GaN single crystal of this invention, and the result which checked the quality is shown.

As the example of the one example experiment of an experiment shows to the process 2 in

drawing 1 as a method of repeating the crystal-growth cycle in the manufacture method of the GaN single crystal of the above-mentioned this invention, it is the first substrate P0. Up, the buffer layer and the GaN single crystal were grown up one by one, and turned the laminating, and it considered as the method of removing each buffer layer at once finally, and separating a GaN single crystal. The first substrate P0 If carried out, the substrate which grew the GaN single crystal layer epitaxially by the MOVPE method was used on the sapphire crystal base material. The buffer layer set thickness to 0.2 micrometers, and set material to ZnO. A crystal-growth cycle shall be repeated 5 times. The GaN single crystal P1 – P5 which are formed in crystal-growth cycle each time All thickness aimed at 300 micrometers. GaN single crystal P5 obtained at the end When full width at half maximum was measured, it was 29sec and the thickness was 305 micrometers.

[0021] In the example of the two example experiment of an experiment, it replaced with the method of repeating the crystal-growth cycle in the above-mentioned example 1 of an experiment, as shown in the process 3 in drawing 1 . whenever the GaN single crystal grew epitaxially, the buffer layer in front of it was removed, and the completely same GaN single crystal as the example 1 of an experiment was produced except having always used the new substrate as the GaN independent single crystal of one sheet. GaN single crystal P5 obtained at the end Full width at half maximum of quality was 28sec(s), and the thickness was 289 micrometers.

[0022] In the example of the three example experiment of an experiment, the completely same GaN single crystal as the example 2 of an experiment was produced except having used the substrate of three layers which consists of silicon on sapphire, a buffer layer of AlN (aluminum nitride), and a GaN single crystal as first substrate in the above-mentioned example 2 of an experiment. The manufacture process of the substrate of three layers is explained briefly. On 300 micrometers in thickness, and the area 5cmx5cm sapphire crystal substrate, AlN was grown epitaxially to the thickness of 500A by the MOVPE method as a buffer layer, material gas was changed with the state, the GaN single crystal was grown epitaxially to the thickness of 2 micrometers by the same MOVPE method, it considered as the surface, and the substrate of three layer structures with a total thickness of about 302 micrometers which consists of a sapphire crystal substrate, an AlN buffer layer, and a surface of a GaN single crystal GaN single crystal P5 obtained at the end by this experiment Full width at half maximum of quality was 25sec(s), and the thickness was 295 micrometers.

[0023] the example of the four example experiment of an experiment — the above-mentioned example 2 of an experiment — setting — the first substrate P0 ***** — as the material (BeO) of the buffer layer in each cycle at the time of repeating the crystal-growth cycle of a GaN single crystal using the same substrate of three layers as the example 3 of an experiment — 0.13 (ZnO) 0.87 The completely same GaN single crystal as the example 2 of an experiment was produced except having used. GaN single crystal P5 obtained at the end by this experiment Full width at half maximum of quality was 28sec(s), and the thickness was 301 micrometers.

[0024] In the example of the five example experiment of an experiment, in order to compare with the quality of the GaN single crystal by this invention, the quality of the GaN single crystal by the conventional manufacture method was investigated. On 300 micrometers in thickness, and the area 5cmx5cm sapphire crystal substrate, the buffer layer with a made from ZnO by the sputtering method thickness of 0.6 micrometers was formed, and the GaN single crystal was grown epitaxially to 250 micrometers in thickness by HVPE on it. The full width at half maximum of the quality of this GaN single crystal was 420sec(s).

[0025] It was checked that the manufacture method of the GaN single crystal of this invention can manufacture the quality GaN single crystal which is not in the former, and it is possible to manufacture in sufficient thickness to use a GaN single crystal as an independent substrate so that clearly [in the above-mentioned experimental result].

[0026] Such a quality and thick GaN single crystal obtained by the manufacture method of this invention is preferably used for uses, such as semiconductor light emitting devices, such as light emitting diode (Light Emitting Diode), laser diode (LD), and super luminescence diode, and an electron device. In a semiconductor light emitting device, it is using the GaN single crystal of this

invention as a substrate, and manufacture of Light Emitting Diode, LD, etc. which have the structure of the same electrode section as the conventional red Light Emitting Diode etc. is attained. What carries out blue luminescence also especially in these is important. Moreover, the efficiency of luminescence of the semiconductor light emitting device will become higher.

[0027] [Quality check experiment of Light Emitting Diode using the GaN single crystal by this invention] Light Emitting Diode using the GaN single crystal obtained by the manufacture method of this invention as a substrate was actually manufactured, and the quality was checked.

Moreover, Light Emitting Diode which uses respectively the GaN single crystal and sapphire crystal of quality as a substrate conventionally was manufactured, and it compared with the quality of Light Emitting Diode which uses the GaN single crystal of this invention as a substrate. As a GaN single crystal of quality, full width at half maximum used the thing of 300sec(s) conventionally. The quality of Light Emitting Diode evaluated about early brightness and an early life. The life measured the brightness after carrying out continuation luminescence by 20mA current for 2000 hours into temperature the atmosphere of 85% of humidity of 85 degrees C, and it asked for the decreasing rate to the brightness in early stages of the brightness, and A and less than two to five decreasing rate % was divided into B, and 5 – 10% of decreasing rates was divided into C and three ranks for less than 2% of decreasing rates. The structure of Light Emitting Diode used as the substrate the GaN single crystal obtained by the manufacture method of this invention, and considered the n-AlGaN clad layer, the InGaN barrier layer of undoping, and the p-AlGaN clad layer as the double heterojunction type composition made to come to grow up one by one on this substrate. The full width at half maximum of the quality of the substrate of the GaN single crystal by this invention is three kinds, 30sec(s), 100sec, and 250sec. All thickness is 280 micrometers. Moreover, the composition ratio of InGaN of a barrier layer considered as two kinds, In0.15Ga0.85N and In0.25Ga0.75N, and experimented by creating a light emitting device about InGaN of each composition ratio. This experimental result is shown in the next tables 1 and 2.

[0028]

[Table 1]

活性層の組成比が In_{0.15}Ga_{0.85}N である LED

の輝度と寿命の比較

基板	FWHM (sec)	初期の輝度 (candela)	寿命
GaN	30	1.8	A
GaN	100	1.4	A
GaN	250	1.2	B
GaN	300	1.1	B
サファイア	—	1.0	C

[0029]

[Table 2]

活性層の組成比が $In_{0.25}Ga_{0.75}N$ である LED
の輝度と寿命の比較

基板	FWHM (sec)	初期の輝度 (candela)	寿命
GaN	30	2.9	A
GaN	100	2.5	A
GaN	250	2.2	B
GaN サファイア	300 —	2.2 2.0	B C

[0030] As shown in Tables 1 and 2, it is early brightness and the point of a life and, as for Light Emitting Diode using the quality GaN single crystal by this invention as a substrate, it turns out that it is Light Emitting Diode superior to the conventional thing.

[0031] Moreover, the following phenomenon has been checked about LD. In the conventional LD which uses a sapphire crystal as a substrate, since the state of the field of the GaN system compound semiconductor layer which will not be in the mirror-plane state where a substrate side is desirable, but is formed in the substrate side since it is the matter with a sapphire crystal difficult for formation of a cleavage plane followed the state of a substrate side, the reflector desirable for LD was not able to be formed. However, since it had thickness quality [the GaN single crystal by this invention], and sufficient, it became easy to obtain the cleavage plane by using a GaN single crystal as a substrate. Moreover, since crystal quality was inferior, although induced emission by current pouring has not been attained in LD using the conventional GaN system compound semiconductor, when constituted and experimented in the stripe laser of the Fabry-Perot resonator using the quality GaN single crystal by this invention as a substrate, induced emission was checked in the room temperature.

[0032]

[Effect of the Invention] As explained in full detail above, the GaN single crystal of this invention is simultaneously equipped with the crystal quality which was not in the former, and sufficient thickness. Moreover, the manufacture method of this invention can offer suitably the GaN single crystal simultaneously equipped with such quality and sufficient thickness. Therefore, in order to obtain Light Emitting Diode which presents efficient blue luminescence, and ultraviolet-rays laser diode or a heat-resistant good semiconductor device, the substrate of a suitable GaN single crystal is offered and the thing of it can be carried out. Moreover, the manufacture method of this invention can manufacture efficiently the improvement in the crystal quality of a GaN single crystal, and not only acquisition of thickness but several quality GaN many single crystals, and is industrial very important technology.

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CLAIMS

[Claim(s)]

[Claim 1] The GaN single crystal whose thickness the full width at half maximum of 2 crystallization X-ray rocking curve is 5–250sec, and is 80 micrometers or more.

[Claim 2] The manufacture method of a GaN single crystal of having the process which was made carrying out thin film growth of the good matter of grid adjustment with a GaN single crystal, turned to the buffer layer up on the substrate whose front face is a GaN single crystal at least, is made carrying out the crystal growth of the GaN, and obtains a GaN single crystal.

[Claim 3] The manufacture method of the GaN single crystal characterized by to remove each buffer layer after making into 1 time of a crystal-growth cycle the process which was made to carry out thin film growth of the good matter of grid adjustment with a GaN single crystal, turned to the buffer layer up on the substrate whose front face is a GaN single crystal at least, is made to carry out the crystal growth of the GaN, and obtains a GaN single crystal and making 1 cycle repeat ***** form the above-mentioned crystal-growth cycle at least on the obtained GaN single crystal, and to obtain a GaN single crystal.

[Claim 4] The process which was made to carry out thin film growth of the good matter of grid adjustment with a GaN single crystal, turned to the buffer layer up on the substrate whose front face is a GaN single crystal at least, is made to carry out the crystal growth of the GaN, and obtains a GaN single crystal is made into 1 time of a crystal-growth cycle. The manufacture method of the GaN single crystal characterized by removing a buffer layer for the above-mentioned crystal-growth cycle for every [1 cycle repeat and] cycle at least, and obtaining a GaN single crystal by using the obtained GaN single crystal as a new substrate.

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

Drawing 1 It is the ** type view showing an example of the process of the manufacture method of the GaN single crystal by this invention.

[Description of Notations]

P0 The first substrate

P1 -Pn GaN single crystal

B1 -Bn Buffer layer

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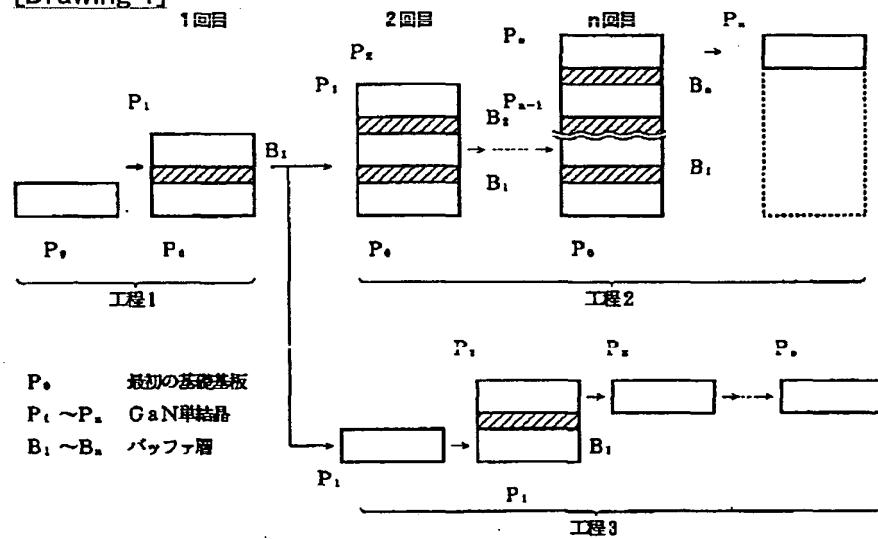
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DRAWINGS

[Drawing 1]



[Translation done.]